

IMPERVIOUS SURFACE CHANGE IN BEIJING FROM 1984 TO 2001

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ABSTRACT:

The change of impervious surface in Beijing from 1984 to 2001 is detected by analyzing Landsat TM images using the Vegetation-Impervious-Soil (V-I-S) model. The end members of the V-I-S model are obtained through minimum noise fraction (MNF) transformation and Spectral Mixing Analysis (SMA) technique. The results show that the impervious surface has increased substantially in Beijing during the time in between.

1. INTRODUCTION

The political and economic reforms in China in the last few decades had spurred unprecedented rate of urbanization (Liu *et al.* 2002). Since the 1980s, urban population has been quadrupled to result in more than 300 new cities. As the nation's capital, Beijing has witnessed an annual population growth of more than 1% in the past twenty years. Such population growth, coupled with the annual GDP increase of more than 10%, resulted in extensive sprawl in Beijing metropolitan area. In this paper, we report a research on using remotely sensed images to examine this urbanization process. Specifically, we examine the change of impervious surface between 1984 and 2001 and characterize the spatial characteristics of this change.

2. DATA AND METHOD

2.1 Study area

As a preliminary study, this research focused on the central area of Beijing which has experienced significant urbanization in the last few decades. To detect the land use change, two TM satellite images taken in October 1984 and May 2001 respectively were acquired. The atmosphere difference between the two images was minimized through radiometric rectification. During the rectification, the digital numbers in the images were converted to atmospheric reflectance using published post-launch gains and offsets (Kuitis *et al.*, 2004). The 2001 image was then registered to the 1984 image through geometric rectification. The registration error is found to be less than one pixel. Figure 1 shows the study area in 1984 and 2001 respectively.

2.2 V-I-S model

Urban area consists of heterogeneous materials such as concrete, asphalt, metals, plastic, soil, buildings, highways, and road (Lu *et al.*, 2004). These materials form various features. Some are differentiable from the image, while the others such as trees and

individual buildings are smaller than the spatial resolution of the sensors. This results in the mixed pixel problem where a pixel contains multiple land use classes instead of a single land use class (Wu *et al.*, 2003). This mixed land use problem presents substantial challenge to the traditional classifiers in remote sensing which are found not capable to handle complex urban landscapes (Lu 2004). To accurately examine the change of impervious surface, the V-I-S model was applied.

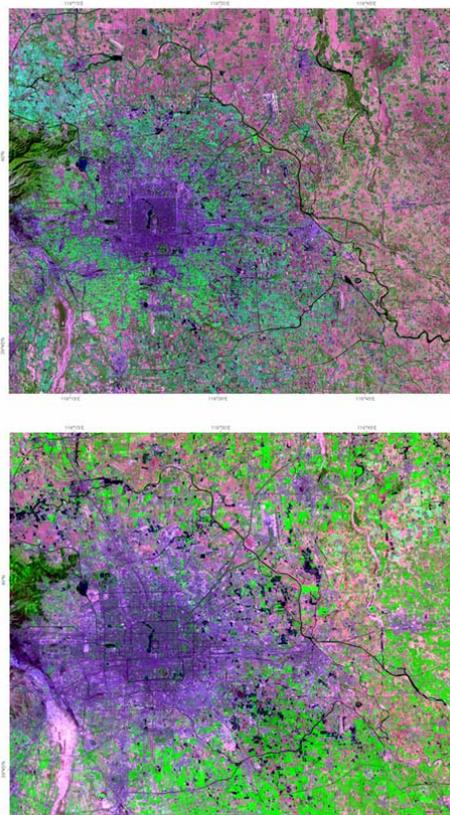


Figure 1. TM image (Band 7-4-2) of October 1984 (up) and May 2001 (down)

The V-I-S model perceives each pixel in the land area of an image as the mixture of three types of land covers: vegetation (V), impervious surface (I), and soil (S) (Ridd, 1995). To infer the total area of the impervious surface in the city, the proportion of impervious surface in each pixel must be derived first. To this end, Linear Spectral Mixture Model (LSMM) which has been widely used in conjunction with V-I-S model was employed (Zhou et al., 2003). LSMM models each pixel as a combination of the end members, which are vegetation, impervious surface, and soil in the case of V-I-S analysis. The reflectance value of each pixel is modeled as a linear combination of the end members. Mathematically, LSMM can be expressed as follows (Adams et al., 1995)

$$R_b = \sum_{i=1}^N f_i R_{ib} + e_b \quad (1)$$

Where R_b = the spectral reflectivity of Band b
 b = the number of spectral bands used
 f_i = rate of each endmember
 e : model fitting error for band b

End member is the pivotal element to the success of V-I-S model. To accurately estimate the proportion of V, I, and S in each mixed pixel, pure samples which contains a single land cover class need to be obtained first. For this purpose, Minimum Noise Fraction (MNF) transformation was first conducted to segregate and equalize the noise. The spectral dimensions of the data were reduced and the inherent dimensionality of the image data is discovered. Figure 3 shows the MNF component space where the triangular space represents landmark components. The corners of the triangle indicate pixels with pure spectral characteristics. Heterogeneous pixels are located inside the triangles.

Using the 2-D scatter plot in Figure 3, spectrally pure pixels were identified and verified through field survey. The end members of the V-I-S model are determined. Spectral angle Mapper (SAM) which is a type of spectral mixing analysis based on the idea of LSMM is then applied (Yuhua et al., 1992). This method calculates the spectral angle between the spectrum of each pixel with that of the endmember so that the pixel is assigned to the best matching class. The output is a classified image.

In addition to vegetation, impervious surface, and soil, water is another land over found in the study area. During MNF processing, water is found to confuse with the shades of the buildings. Using MNDWI calculation, a water mask can be built to minimize the influence of water (Xu et al., 2005). Some parts of the area have dried water bed which can also be confused with buildings in the urban area. For these features, a mask is also needed so that they can be differentiated from the impervious surface.

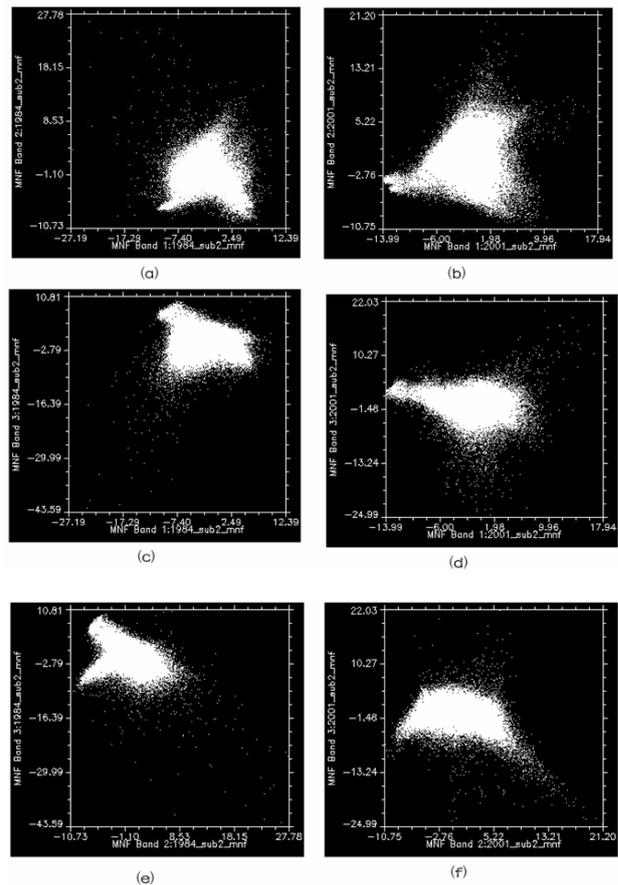


Figure 3. Feature spaces for first three MNF components for 1984 and 2001: (a) MNF1 and 2 of 1984; (b) MNF1 and 2 of 2001; (c) MNF1 and 3 of 1984; (d) MNF1 and 3 of 2001; (e) MNF2 and 3 of 1984; (f) MNF2 and 3 of 2001

3. RESULTS AND DISCUSSION

For both images, a threshold value to classify a pixel into impervious pixel is established through field investigation and with reference to the land use map of the 1980s. Using this threshold value, the percentage of impervious pixels in each image was then computed.

Figure 4 shows the impervious surface in Beijing in 1984 and 2001 respectively. It can be seen that crop farm and soil show rather different change pattern. For the fourth ring of Beijing, there was 1.2% vegetated area in 1984 but 1.8% in the year of 2001. The increase of the green area confirmed the effectiveness of the effort by the government to increase Beijing's greenness. In 1984, there is 0.766% soil area including farmlands. By 2001, all previous farmland have been transformed to impervious surface, in particular buildings and transportation. Currently, research is being conducted to infer the land cover composition of different land use categories. We hope the results will help to build a linkage between land cover and land use change in Beijing.

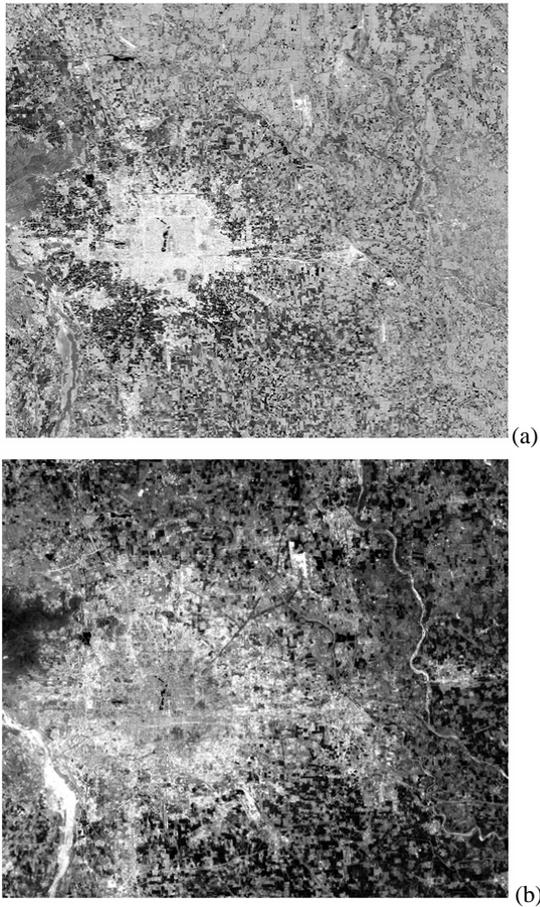


Figure 4. Impervious surface images (a):1984; (b):2001

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